

(1390 REV. 5-93) US DEPT. OF COMMERCE PATENT & TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 111363
<b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371</b>		U.S. APPLICATION NO. (if known, sec 37 C.F.R.1.5) <b>09/980458</b>
INTERNATIONAL APPLICATION NO. PCT/EP00/05203	INTERNATIONAL FILING DATE June 7, 2000	PRIORITY DATE CLAIMED June 11, 1999
TITLE OF INVENTION OPTICAL SYSTEM FOR LASERS		
APPLICANT FOR DO/EO/US Daniel KOPF		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information: 1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371. 2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371. 3. <input checked="" type="checkbox"/> This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1). 4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date. 5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2)) a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau). b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau. c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US) 6. <input type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)). 7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau). b. <input type="checkbox"/> have been transmitted by the International Bureau. c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired. d. <input type="checkbox"/> have not been made and will not be made. 8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)). 9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). 10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)). <b>Items 11. to 16. below concern other document(s) or information included:</b> 11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98. 12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. <input checked="" type="checkbox"/> A FIRST preliminary amendment. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment. 14. <input type="checkbox"/> A substitute specification. 15. <input type="checkbox"/> Entitlement to small entity status is hereby asserted. 16. <input checked="" type="checkbox"/> Other items or information: A submission of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).		

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17. <input checked="" type="checkbox"/> The following fees are submitted:  <b>Basic National fee (37 CFR 1.492(a)(1)-(5)):</b>  Search Report has been prepared by the EPO or JPO ....\$890.00  International preliminary examination fee paid to USPTO (37 CFR1.482) .....\$710.00  No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) .....\$740.00  Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO .....\$1,040.00  International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) .....\$ 100.00  <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>	<b>CALCULATIONS</b>	<b>PTO USE ONLY</b>																																				
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<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th style="width:20%;">Claims</th> <th style="width:20%;">Number Filed</th> <th style="width:10%;">Number Extra</th> <th style="width:10%;">Rate</th> </tr> <tr> <td>Total Claims</td> <td>13- 20 =</td> <td>0</td> <td>X \$ 18.00</td> </tr> <tr> <td>Independent Claims</td> <td>2- 3 =</td> <td>0</td> <td>X \$ 84.00</td> </tr> <tr> <td colspan="3">Multiple dependent claim(s)(if applicable)</td> <td>+ \$280.00</td> </tr> <tr> <td colspan="3"><b>TOTAL OF ABOVE CALCULATIONS =</b></td> <td>\$890.00</td> </tr> <tr> <td colspan="3">Reduction by 1/2 for filing by small entity, if applicable.</td> <td>- \$</td> </tr> <tr> <td colspan="3"><b>SUBTOTAL =</b></td> <td>\$890.00</td> </tr> <tr> <td colspan="3">Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 month from the earliest claimed priority date (37 CFR 1.492(f)).</td> <td>+ \$</td> </tr> <tr> <td colspan="3"><b>TOTAL NATIONAL FEE =</b></td> <td>\$890.00</td> </tr> </table>	Claims	Number Filed	Number Extra	Rate	Total Claims	13- 20 =	0	X \$ 18.00	Independent Claims	2- 3 =	0	X \$ 84.00	Multiple dependent claim(s)(if applicable)			+ \$280.00	<b>TOTAL OF ABOVE CALCULATIONS =</b>			\$890.00	Reduction by 1/2 for filing by small entity, if applicable.			- \$	<b>SUBTOTAL =</b>			\$890.00	Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 month from the earliest claimed priority date (37 CFR 1.492(f)).			+ \$	<b>TOTAL NATIONAL FEE =</b>			\$890.00	\$	
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b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$\_\_\_\_\_ to cover the above fees. A duplicate copy of this sheet is enclosed.

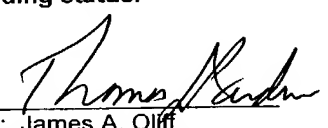
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**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:  
 OLIFF & BERRIDGE, PLC  
 P.O. Box 19928  
 Alexandria, Virginia 22320

Date: December 4, 2001

NAME: James A. Oliff  
 REGISTRATION NUMBER: 27,075  
  
 NAME: Thomas J. Pardini  
 REGISTRATION NUMBER: 30,411

U.S. APPLICATION NO. (if known) <b>09/980458</b> C.F.R. 1.5)		INTERNATIONAL APPLICATION NO. PCT/EP00/05203		ATTORNEY'S DOCKET NUMBER 111363	
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SEND ALL CORRESPONDENCE TO: OLIFF & BERRIDGE, PLC P.O. Box 19928 Alexandria, Virginia 22320					
Date: <u>December 4, 2001</u>				<div style="text-align: center;"> NAME: James A. Oliff REGISTRATION NUMBER: 27,075</div> <div style="text-align: center;"> NAME: Thomas J. Pardini REGISTRATION NUMBER: 30,411</div>	

09980458 09/980458

JC10 Rec'd PCT/PTO 0 4 DEC 2001

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Daniel KOPF

Application No.: U.S. National Stage  
of PCT/EP00/05203

Filed: December 4, 2001

Docket No.: 111363

For: OPTICAL SYSTEM FOR LASERS

PRELIMINARY AMENDMENT

Director of the U.S. Patent and Trademark Office  
Washington, D. C. 20231

Sir:

Prior to initial examination, and after entry of the annexes to the IPER, please amend the above-identified application as follows:

IN THE CLAIMS:

Please replace claims 3, 5-6, 9-10 and 12-13 as follows:

3. (Amended) Laser system according to claim 1 characterized in that said laser beam (3) is reflected back onto itself after passing said nonlinear optical material (1a).
5. (Amended) Laser system according to claim 1 comprising a dichroic mirror (9) or a polarizing beam splitter.
6. (Amended) Laser system according to claim 1, wherein said nonlinear optical material (1,1b) is
  - o a semiconductor saturable absorber; or



- o one fixing means, for instance a screw (13a) for fixing said optical component (12) in the recess;

wherein said optical component (12) is rotatable around its axis in said recess.

12. (Amended) Adjustable optical means according to claim 10, wherein the defined touching surfaces (11) are shaped in the form of V-grooves.

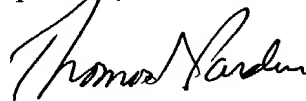
13. (Amended) Adjustable optical means according to claim 10, wherein said optical component (12) and said recess are substantially cylindrical.

#### REMARKS

Claims 1-13 are pending. By this Preliminary Amendment, claims 3, 5-6, 9-10 and 12-13 are amended to eliminate multiple dependencies. Prompt and favorable examination on the merits is respectfully requested.

The attached Appendix includes marked-up copies of each rewritten claim (37 C.F.R. §1.121(c)(1)(ii)).

Respectfully submitted,



James A. Oliff  
Registration No. 27,075

Thomas J. Pardini  
Registration No. 30,411

JAO:TJP/cmm

Attachment: Appendix

Date: December 4, 2001

**OLIFF & BERRIDGE, PLC**  
**P.O. Box 19928**  
**Alexandria, Virginia 22320**  
**Telephone: (703) 836-6400**

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## APPENDIX

## Changes to Claims:

The following are marked-up versions of the amended claims:

3. (Amended) Laser system according to claim 1 ~~or 2~~ characterized in that said laser beam (3) is reflected back onto itself after passing said nonlinear optical material (1a).
5. (Amended) Laser system according to claim 1 ~~any one of the preceding claims~~ comprising a dichroic mirror (9) or a polarizing beam splitter.
6. (Amended) Laser system according to claim 1 ~~one of the preceding claims~~, wherein said nonlinear optical material (1,1b) is
  - a semiconductor saturable absorber; or
  - a nonlinear optical crystal used for frequency conversion such as second harmonic, third harmonic, multiple harmonic generation or optical parametric oscillation or amplification; or
  - lithium borate (LBO), beta-barium borate (BBO), potassium titanyl phosphate (KTP), cesium lithium borate (CLBO) or periodically poled lithium niobate (PPLN).
9. (Amended) Optical system according to claim 7 ~~one of claims 7 or 8~~, wherein said first optical material (1,1b) and/or said second optical material (1c) is
  - a semiconductor saturable absorber; or
  - a nonlinear optical crystal used for frequency conversion such as second harmonic, third harmonic, multiple harmonic generation or optical parametric oscillation or amplification; or
  - lithium borate (LBO), beta-barium borate (BBO), potassium titanyl phosphate (KTP), cesium lithium borate (CLBO) or periodically poled lithium niobate (PPLN).

10. (Amended) Adjustable optical means for an optical system according to claim 1 ~~any one of the claims 1 through 9~~, comprising

- a optical component (12), such as a laser mirror or a nonlinear optical material, with one or two wedged surfaces (14) and
- a holder for said optical component (12), preferably to be positioned onto an optical platform or the like, comprising
  - o means for supporting said optical component (12) which supporting means comprise four defined touching surfaces (11);
  - o one recess for inserting said optical component (12);
  - o one fixing means, for instance a screw (13a) for fixing said optical component (12) in the recess;

wherein said optical component (12) is rotatable around its axis in said recess.

12. (Amended) Adjustable optical means according to claim 10 ~~or 11~~, wherein the defined touching surfaces (11) are shaped in the form of V-grooves.

13. (Amended) Adjustable optical means according to claim 10, ~~11 or 12~~, wherein said optical component (12) and said recess are substantially cylindrical.



## OPTICAL SYSTEM FOR LASERS

**Field of the Invention:** This invention relates to the field of lasers and optics where the laser beam passes through or is reflected from the surface of an optical material which has limited durability under light exposure.

5 Furthermore, this invention relates to holders for optical components.

**Background of the invention:** Solid state optical materials, such as for example the solid state laser materials or non-linear optical materials, are usually interesting for several reasons. They can, for instance, come in small sizes, can withstand high intensities on a spot, can be manufactured in high quantities, and are easy to handle  
10 because they are solid (in comparison to, for example, liquid dyes or gases). However, in some cases these materials do not live for extended times when being exposed to a certain light intensity. This can occur, for example, when a nonlinear crystal is used for frequency-converting the laser light, whereby the laser beam is usually focused onto a small spot or has high peak powers. Similarly, semiconductors  
15 may show long-term degradation effects which can limit the time of use of semiconductor materials when exposed to a certain intensity on a spot. Any kind of other optical elements may suffer from similar effects. The goal of this invention is to use up all or a substantial fraction of the available material and not only the material at a certain spot in the material. Instead of moving the material transversely with regard  
20 to the incident light beam and thereby moving the light spot to another position inside the material, a very simple technique to move the spot on the material is described herein; this technique allows the use of different spots on the material.

As for the holder for optical components, the goal is to make simple, easy-to-manufacture, and easy-to-use holders for optical components. Of special interest are  
25 optical holders for laser mirrors which are cost-effective, use a minimum of adjusters while still allowing for a certain degree of adjustability.

**State of the art:**

**Nonlinear optics:** Many nonlinear optical crystals that are used for frequency conversion have limited usability when being exposed to light of a certain intensity.  
30 For example, the well-known crystal potassium titanyl phosphate (K<sub>2</sub>TiOPO<sub>4</sub>, KTP) has been reported to suffer from long-term degradation effects, all of which are still under investigation and one of which was called "grey tracking". On the market, many

Neodymium-based laser sources that are converted into the green by second harmonic generation use KTP as the doubling crystal, both as intra cavity or as extra cavity, and have shown limited long-term operation due to the KTP crystal degradation properties under light exposure. Long-term degradation is often also reported for nonlinear crystals which are used to convert (laser) light into the ultra violet. For example, beta-barium borate, known as BBO, is well known for this application but has shown long-term degradation effects over a time duration in the order of 100 or 1000 hours. In some cases, the problem was solved by transversely moving the crystal with respect to the incident beam, which results in a different spot being "used up". The disadvantage, however, is that usually the crystal has to be moved while keeping its angle orientation constant at very high precision to ensure optimum frequency conversion efficiency. This must often be done by using relatively expensive translation stages.

*Semiconductor materials and surfaces:* Semiconductors usually have lower optical damage thresholds than other solid state optical materials such as laser crystals or optical glass. Also well known is the limited life time of laser diodes which is due to both bulk material and surface degradation, again showing that the issue of long-term degradation becomes apparent in semiconductors. Semiconductor materials are also used for ultra short pulse generation from lasers, particularly solid state lasers. Such devices are for example the SESAMs (semiconductor saturable absorber mirrors), which were demonstrated to generate pulses at various wavelengths in a variety of laser systems. In some publications, it is pointed out that their life time is limited and optical degradation occurs on the spot being exposed to the laser beam. Again, transversely moving the SESAM to another position such that a "fresh", unused spot is being used would enhance the laser life time by a factor corresponding to as many times as the SESAM can be moved. However, translation stages that are used for this purpose are costly and of rather big size or have to be replaced quite frequently.

*Linear and other optical materials:* Aside from the materials listed above, similar degradation effects are also apparent in any kind of optical materials, depending on the type of material, the incident intensity and/or the peak intensity, the temperature of the material, the incident light wavelength, etc. For example, ultra violet wavelengths tend to damage many optical materials over time if reaching a certain intensity. Also in these cases, the solution that has so far been presented has usually been the replacement of the material after usage or the transverse movement.

*Mirror holders and optical holders:* The mirror holders used most commonly still need, for each adjustable axis, one adjustment screw. In addition, one set screw is necessary to hold the adjusted mirror in place. Furthermore, such standard mirror holders have to be fixed onto the optical platform or onto a post with a fixing screw.

- 5 Mirror holders of this type can be found in the repertoire of most opto-mechanical components vendors. However, the number of screws required to give the freedom to make all the adjustments necessary, results in increased costs, more complicated assembly procedures, and higher risks of failure during long-term operation. Therefore, a mirror holder would be required using a minimum of screws and  
10 adjusters allowing an adjustment within a certain range before all screws are locked in place.

#### **Summary of the invention:**

- The invention relates to the field of lasers and optics where the laser beam passes  
15 through or is reflected from the surface of a material which has limited durability under light exposure. To overcome the problems described above the invention describes a simple technique by way of which the spot is moved across the material, thereby enhancing the lifetime of the laser or optical system since more than one sole spot of the same material is used. This technique may be used in combination with material  
20 being used inside a laser cavity as well as outside a laser cavity, or in general in any application where high intensity light is exposed to a part of an optical material.

- Furthermore, this invention relates to optical holders for optical components. An optical holder is described, which is both simple and stable. For such an optical holder only a minimum of screws is used: for example one set screw and one fixing  
25 screw but no adjustment screw. Nevertheless, the holder allows adjusting both the vertical and the horizontal angle of the optical component within a certain range. The holder relies on a double-V-groove supporting technique, which holds the optical component in place in a pre-determined way, unaffected from machining tolerances.

#### **Brief description of the drawings:**

30 Fig.1 shows the principle scheme of the invention;

Fig.2a shows a way for using the scheme of Fig.1 for frequency conversion;

Fig.2b  $\alpha$ , 2b  $\beta$  and 2b  $\gamma$  show the setup of Fig.2a in a more generalized form;

Fig.3 shows the propagation of the frequency-converted beam and the fundamental beam inside the nonlinear optical material;

Fig.4a, 4b and 4c show the principle of an optical holder according to the invention, whereby Fig.4a shows a front view, Fig.4b a cross-sectional view perpendicular to Fig.4a and Fig.4c a top view; Fig.4d is an alternative embodiment according to Fig.4a;

Fig.5a, 5b and 5c show, according to Fig. 4a, 4b and 4c, an alternate embodiment for an optical holder and

Fig.6a, 6b and 6c show, according to Fig. 4a, 4b and 4c, a third alternative for an optical holder.

### **Description of the invention:**

*Scheme 1:* Scheme 1 of this invention is shown in figure 1. Here a reflective optical material 1 is used which is exposed to incident light being imaged or focused through a lens 2. If an incident beam 3 is collimated before reaching the lens 2, the lens 2 will focus the incident beam approximately onto a spot 4 on the optical material 1 (depending on the degree of collimation), the optical material 1 being positioned approximately at a distance corresponding to the focal length  $f$  away from the lens 2.

If a reflective mirror M1 is put before the lens 2 at a distance corresponding to about the focal length  $f$  of the lens, then the spot 4 on the optical (laser) material 1 can be shifted simply by adjusting the angle of the reflecting mirror M1. If M1 is positioned at a distance away from the lens that corresponds exactly to  $f$ , the beam propagation axis 5 after the lens 2 (before the optical material 1) does not change its angle at all.

Thereby, any change of the angle of the mirror M1 will result in a direct change of the position of the light spot 4 on the optical material 1 without affecting the relative position of the beam propagation axis 5. It becomes evident that the mechanical tolerances for the mirror M1 are uncritical as the relative position of the beam propagation axis 5 remains constant.

The scheme shown in Figure 1 can for example be used inside a laser resonator, i.e. intra cavity. In a standing wave laser resonator, the scheme of Figure 1 can be one end of the cavity, in which case the optical material 1 preferably is adjusted such that

In Figure 2a there is shown a way to use the scheme described in Figure 1 for frequency conversion in combination with a nonlinear crystal 1a, as an example for the optical material, positioned close to the focus  $f$  of the lens 2 the incident beam 3 is focused at. In this case the incident beam 3 passes through the nonlinear crystal 1a and is reflected back onto itself, for example by a reflective surface 7 which can be positioned on the back side of the nonlinear crystal 1a (as in the figure 2a) or which can be positioned apart (not shown). The orientation of the nonlinear crystal 1a, its cut and length can be determined by standard rules well known in the nonlinear optics literature. Given the parameters of the incident beam 3 and the focal length  $f$  of the lens 2, the beam parameters at the crystal can be determined using calculation formulas that are standard and which are useful to determine the parameters of the crystal for obtaining an optimum frequency conversion, as described in the nonlinear optics literature. According to the scheme of figure 2a, the frequency-converted beam 8 propagates back after having passed the mirror M1 again along the same axis as the incident beam 3. Then the two beams may be separated from each other by using, for example, a dichroic mirror 9, or a polarizing beam splitter. Likewise, this scheme has the advantage that regardless of the tilt of the mirror M1 and therefore regardless

of the position of the spot 4 being used on the optical material 1, 1a, the back-reflected beam 6 (or the frequency-converted beam 8 respectively) remains on the axis and does, on the whole, not change its properties, as for instance its ray profile. If, however, the two beams are chosen not to be on the same axis, there may be used  
 5 other means to separate them from each other, such as for example a mirror edge.

A generalized setup is shown in Figure 2b, where the single lens 2 of Figure 2a is replaced by a general optical imaging system described by an ABCD-matrix (see Siegman, "Lasers", University Science Books, pages 581 ff). The ABCD-matrix  
 10 formulism is known both in the ray optics and paraxial optics and is used to calculate the imaging of rays as well as of paraxial beams.

In a first approach, the ABCD matrix is used for imaging rays through the optical system. Generally, the ABCD-matrix formulism allows to image any optical ray ( $r, r'$ ) where  $r$  denotes the offset from the optical axis and  $r'$  the angle of the beam. After having passed the optical system described by the ABCD-matrix ,

$$\begin{pmatrix} AB \\ CD \end{pmatrix}$$

( see also Fig.1) the optical ray changes its offset and angle as calculated by simple  
 15 matrix calculations:

$$\begin{pmatrix} R \\ R' \end{pmatrix} = \begin{pmatrix} AB \\ CD \end{pmatrix} * \begin{pmatrix} r \\ r' \end{pmatrix} = \begin{pmatrix} Ar + Br' \\ Cr + Dr' \end{pmatrix}$$

This is used for calculating the path of different rays emerging from the same point of the angle-adjustable reflective mirror M1 of Figure 2a and Figure 2b. These rays are all on axis and therefore  $r=0$ . The different angles are accounted for by corresponding  
 20 different values for  $r'$ . The angle-adjustable mirror M1 is followed by the optical system described by the ABCD-matrix. The resulting outcoming beams should now be all parallel to the optical axis, if  $R'=0$ , which leads to the condition that  $Cr+Dr'=0$ . This should be true for all  $r'$ . Taking into account that  $r=0$ , this leads to the condition  $D=0$ . In generalized terms, any optical system described by an ABCD-matrix with  $D=0$   
 25 will result in analogous beam paths as described in Figure 2a.

In a second approach, the ABCD matrix is used for calculating the size of the laser spot 4b at the position of a first crystal 1b. According to the rules given in "Lasers", Siegman, the laser beam incident on the angle-adjustable mirror M1 can be described

in generalized parameters (p, q) instead of the parameters (r, r'). Given these laser beam parameters, the same ABCD matrix can now be used to determine the size of the laser spot 4b on the crystal 1b. Since D=0 is already fixed, the other parameters A, B, and C can be chosen in order to obtain a predetermined spot size on the crystal 1b.

Figure 2b alpha, beta and gamma show different possible schemes obtained following the guidelines given above. In Figure 2b beta an example is shown how two crystals in series can be illuminated by the laser beam which first passes the angle-adjustable mirror, then a first optical system described by

$$\begin{pmatrix} A1B1 \\ C1D1 \end{pmatrix}$$

then the first crystal 1b, followed by a second optical imaging system

$$\begin{pmatrix} A2B2 \\ C2D2 \end{pmatrix}$$

and then the second crystal 1c. In this case, the conditions for the second optical imaging system

$$\begin{pmatrix} A2B2 \\ C2D2 \end{pmatrix}$$

are different because there is the aim to ensure that parallel rays entering the system will again come out as parallel rays. This will be the case when R'=0 and thus C2=0.

Figure 2b gamma shows a simple embodiment using two lenses for the second optical imaging system

$$\begin{pmatrix} A2B2 \\ C2D2 \end{pmatrix}$$

This can be accomplished, for example, if the first lens 10a is positioned at a distance L1, corresponding to its focal length, from the first crystal 1b, and the second lens 10b separated from the first lens by a distance corresponding to the sum of the focal length of the first and the second lens L1, L2, and the second crystal 1b positioned in a distance corresponding to the focal length L2 of the second lens 10b. In a practical setup, for example, L1=11 mm, f1=11 mm, L2=11+8=19mm, f2=8mm, L3=8mm. In

these setups, the laser beam properties at the second crystal 10b may also be obtained by using the same matrix

$$\begin{pmatrix} A2B2 \\ C2D2 \end{pmatrix}$$

for the calculation of those parameters. The setup of Figure 2b gamma with the above parameters can be used, for example, to generate ultraviolet laser light from pulsed infrared laser light. For this purpose, non-critically phase-matched LBO can be used as the first crystal 10a, and critically phase-matched LBO as the second crystal 10b.

In figure 2a any walk-off is neglected that might occur inside the optical material between the fundamental (i.e. incident) and the frequency-converted beam, which results in the two beams being on the same axis. However, the same scheme can be used if (even strong) walk-off will result. As shown in Figure 3, even then, the frequency-converted beam 8 and the fundamental (incident) beam 3 will still be on axis. The frequency-converted beam 8 travels along a different axis inside the nonlinear optical material 1a. All beams, however, will exit the material on parallel axes, as shown in Figure 3. After being reflected on the reflector 7a, the back-travelling beams 8 and 3 are combined finally in the same axis when exiting the front side of the nonlinear optical material 1a. The same considerations apply when the reflecting surface 7a is directly attached to the back side of the nonlinear optical material 1a, perpendicular to the axis of the incident beam 3. These considerations also apply for any kind of birefringent optical material and are not necessarily limited to nonlinear optical materials.

Generally, in all schemes described above and shown in the figures the lens 3 can also be replaced by a reflective mirror with corresponding focal length. Likewise, the lens or reflective focusing mirror does not have to be spherical, as would be most common in many applications. But it could also be a cylindrical lens or a cylindrical focusing mirror, in which case all considerations above only apply in one transverse direction. Furthermore, the lens does not have to be a plano-concave lens, as depicted in all figures for simplicity, but it could be any kind of focusing means. For example, achromatic lenses, doublets, cylindrical lenses, parabolic mirrors, and many more would apply. Aberration corrected lenses and parabolic mirrors would even have advantages in the sense that off-axis angle aberrations can be reduced in



comparison to other types of lenses. As long as the conditions for the (ABCD)-matrix are fulfilled as described above - alternatively a lens system could be applied.

Any features depicted in the figures may be put together in arbitrary combinations. A person skilled in optics and laser physics might find solutions falling within the scope of this invention.

Figure 4 shows the technical drawing of one possible setup of a simple and stable optical holder, that needs only two screws. The holder is machined out of a solid aluminum block. Other materials may also be suitable. The machining may be done from three sides. As a non limiting example, the holder shown in Figure 4 is designed for holding an optical component 12 or a laser mirror with 12.7 mm diameter and 9.5 mm length. It is to be understood that the holder can be made substantially smaller or larger. A first hole H1 holding for example the laser mirror has a diameter somewhat larger than 12.7 mm, for example 13.5 mm, except for the elevated section on which the mirror is going to sit on. A second hole H2, which is perpendicular to the first hole H1 divides this elevated section into four touching surfaces 11. The optical component, when put into the hole H1, will rest on these four defined touching surfaces 11 in a definite way. These surfaces may be shaped differently, as for instance as point surfaces or in the form of a V-groove (Fig.4d). The optical component 12 may be chosen such as to have one or both of its surfaces 14 wedged (dotted line in Fig.4b). Then the rotation of the optical component 12 around its axis, as indicated in Figure 4b with the circled arrow to the right, results in a fine change of the vertical angle of the wedged surface 14. This is the way to have to achieve a fine tuning of the vertical angle on the wedged surfaces before a set screw 13a on the top of the optical holder will be fixed. Once the vertical angle and the set screw 13a are fixed, the holder can still be horizontally rotated and adjusted, and will finally be fixed to an optical platform or post (not shown) by a second screw 13b.

The optical component 12 can, for example, be a laser mirror where the wedged surface is coated with a reflective coating for the wavelength of interest. Also, the optical component could be used in transmission rather than in reflection, in which case the surface angle can again be pre-tuned due to a wedge. Any other optical materials can be used similarly.

Another setup for an optical holder is shown in Figure 5. Only the first hole H1 for holding an optical component is provided and the touching surfaces are made as two

parallel sections 11b for supporting the optical component 12. Such a type of an optical holder has the advantage of being particularly simple to manufacture. It can be manufactured by machining from two sides only.

Figure 6 shows a third alternative for an optical holder where the first hole H1' is made as a simple hole only with no supporting section protruding like in the previous two embodiments. This first hole H1' can then be made such that the optical component 12 will fit in tightly, with the set screw 13a holding the component in place.

Alternatively, glue may be used instead or in addition to the set screw 13a. If only glue is used, this results in a mirror holder which will require one single screw only for mounting the optical holder onto the optical platform. Before the glue will be dry, it will still be possible to adjust the angle of the wedged surface vertically by rotating the optical component around its axis.

Generally, all features mentioned above may be combined in arbitrary ways. Also, features of optical holders known in the art may be combined with features of this invention.

### **Examples for Application**

This invention can be used in laser or optical systems. In particular, if such systems contain an optical material which degrades with time under light exposure, this invention may be a simple solution as to how to increase the overall lifetime of the laser or optical system. As an example, in a typical laser using a SESAM for the generation of picosecond or femtosecond pulses, the beam diameter may be in the order of 100 micro meters. The overall area of the SESAM, however, can be much larger than the size of the laser spot. Given a SESAM size of for example 5mm x 5mm, this will result in approximately 625 spots that can be used over the SESAM surface. This will result in 625.000 hours of operation provided that each spot will endure about 1.000 hours of operation.

For optical materials that are inhomogeneous, this invention may be used to search for a good spot or avoid bad spots by tilting M1 until the desired spot quality is reached.

Another example is the generation of ultra violet light (UV) according to the setup of Figure 2a: To accomplish nonlinear optical frequency conversion from the green into the UV, for example BBO can be used as the optical material in the configuration of Figure 2a. M1 is made reflective for both the incident green light and the back-

reflected frequency-doubled ultra-violet light. The lens is made transmissive for both wavelengths. The walk-off apparent in BBO is compensated according to the scheme of figure 3. The dichroic mirror can be used to separate the two wavelengths. As an alternative, M1 can be made high transmissive for the UV and reflective for the  
5 incident wavelength, in which case M1 would act as the dichroic mirror. However, any tilt of M1 would then result in a change of the UV output direction.

If a cylindrical lens or a cylindrical mirror or any other focusing means is used that only acts in one transverse direction, this would generate an asymmetric beam inside the optical material. This can result in a number of advantages: In an optical material  
10 such as a nonlinear optical crystal, the different beam properties in the two transverse directions can each separately be well matched to the requirements for optimum frequency conversion according to standard nonlinear optics formulas. For example, the angle acceptance for frequency conversion in an optical material may be higher in the vertical transverse direction than in the horizontal direction, in which case a  
15 stronger focusing condition is preferably used in the vertical direction. Likewise, walk-off may occur predominantly in one transverse direction, in which case the focusing condition can also be matched to the walk-off angle. An asymmetric beam inside a vertically squeezed nonlinear optical crystal can result in a one-dimensional heat flow which can increase the thermal load the crystal can take in comparison to radial  
20 cooling.

The optical holder described in this invention may be used in combination with the first objective of the invention. For example, it may be used as holder for the optical material in a setup such as described in Figures 1 to 3.

## Appendix 1: CLAIMS

1. Laser system for using nonlinear optical effects, such as generating ultraviolet light, comprising at least

a laser setup for generating a laser beam (3),

a nonlinear optical material (1a), such as a nonlinear optical crystal used for frequency conversion such as second harmonic, third harmonic, multiple harmonic generation or optical parametric oscillation or amplification,

an optical system with imaging means for imaging said laser beam (3) onto said nonlinear optical material (1a), which imaging means comprise

- at least an optical imaging system (2) for focusing said laser beam onto the nonlinear optical material (1a) and
- at least an optical means (M1) for changing the angle of the propagation axis of said laser beam (3),

- o whereby said optical imaging system is positioned between said optical means (M1) and said nonlinear optical material (1a), and may be described by a

$$\begin{pmatrix} AB \\ CD \end{pmatrix} - \text{matrix},$$

whereby D is substantially zero.

2. Laser system according to claim 1 characterized in that said optical means (M1) is a part of a resonator of said laser setup.

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3. Laser system according to claim 1 or 2 characterized in that said laser beam (3) is reflected back onto itself after passing said nonlinear optical material (1a).
4. Laser system according to claim 3 characterized in that said laser beam (3) is reflected back onto itself by a reflective surface (7a) on the back side of said nonlinear optical material (1a).
5. Laser system according to any one of the preceding claims comprising a dichroic mirror (9) or a polarizing beam splitter.
6. Laser system according to one of the preceding claims, wherein said nonlinear optical material (1,1b) is
  - o a semiconductor saturable absorber; or
  - o a nonlinear optical crystal used for frequency conversion such as second harmonic, third harmonic, multiple harmonic generation or optical parametric oscillation or amplification; or
  - o lithium borate (LBO), beta-barium borate (BBO), potassium titanyl phosphate (KTP), cesium lithium borate (CLBO) or periodically poled lithium niobate (PPLN).
7. Optical system for a laser system with an optical material (1,1b), which has limited durability under light exposure, comprising
  - at least first imaging means for imaging a laser beam (3) onto said first optical material (1,1b), which imaging means comprise
    - at least a first optical imaging system (2) for focusing said laser beam (3) onto said first optical material (1,1b) and

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- at least a first optical means (M1) for changing the angle of the propagation axis of said laser beam (3),
  - o whereby said first optical imaging system is positioned between said first optical means (M1) and said first optical material (1,1b), and may be described by a

$$\begin{pmatrix} AB \\ CD \end{pmatrix} - \text{matrix},$$

whereby D is substantially zero; and

- o whereby said first optical means (M1) is a part of a resonator of said laser system.

8. Optical system according to claim 7 comprising

second imaging means for imaging said laser beam (3) onto a second optical material (1c) whereby the second imaging means comprise

- at least a second optical imaging system (2) for focusing said laser beam (3) onto the second optical material (1c) and
- at least a second optical means for changing the relative position of the propagation axis of the laser beam (3), whereby said second optical imaging system is positioned between said second optical means and said second optical material (1c), and may be described by a

$$\begin{pmatrix} AB \\ CD \end{pmatrix} - \text{matrix},$$

whereby C is substantially zero.

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9. Optical system according to one of the claims 7 or 8, wherein said first optical material (1,1b) and/or said second optical material (1c) is
- o a semiconductor saturable absorber; or
  - o a nonlinear optical crystal used for frequency conversion such as second harmonic, third harmonic, multiple harmonic generation or optical parametric oscillation or amplification; or
  - o lithium borate (LBO), beta-barium borate (BBO), potassium titanyl phosphate (KTP), cesium lithium borate (CLBO) or periodically poled lithium niobate (PPLN).
10. Adjustable optical means for an optical system according to any one of the claims 1 through 9, comprising
- a optical component (12), such as a laser mirror or a nonlinear optical material, with one or two wedged surfaces (14) and
  - a holder for said optical component (12), preferably to be positioned onto an optical platform or the like, comprising
    - o means for supporting said optical component (12) which supporting means comprise four defined touching surfaces (11);
    - o one recess for inserting said optical component (12);
    - o one fixing means, for instance a screw (13a) for fixing said optical component (12) in the recess;

wherein said optical component (12) is rotatable around its axis in said recess.

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11. Adjustable optical means according to claim 10, wherein the length of said defined touching surfaces (11) is smaller than the distance between said defined touching surfaces (11).
12. Adjustable optical means according to claim 10 or 11, wherein the defined touching surfaces (11) are shaped in the form of V-grooves.
13. Adjustable optical means according to claim 10, 11 or 12, wherein said optical component (12) and said recess are substantially cylindrical.

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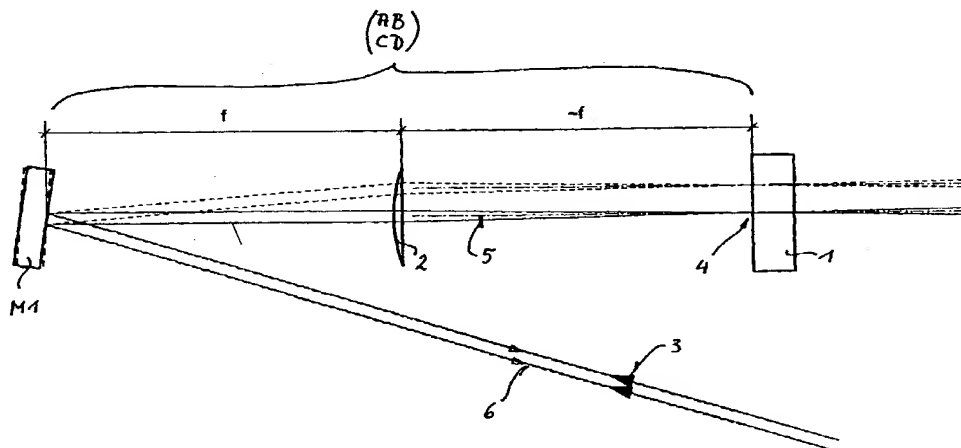
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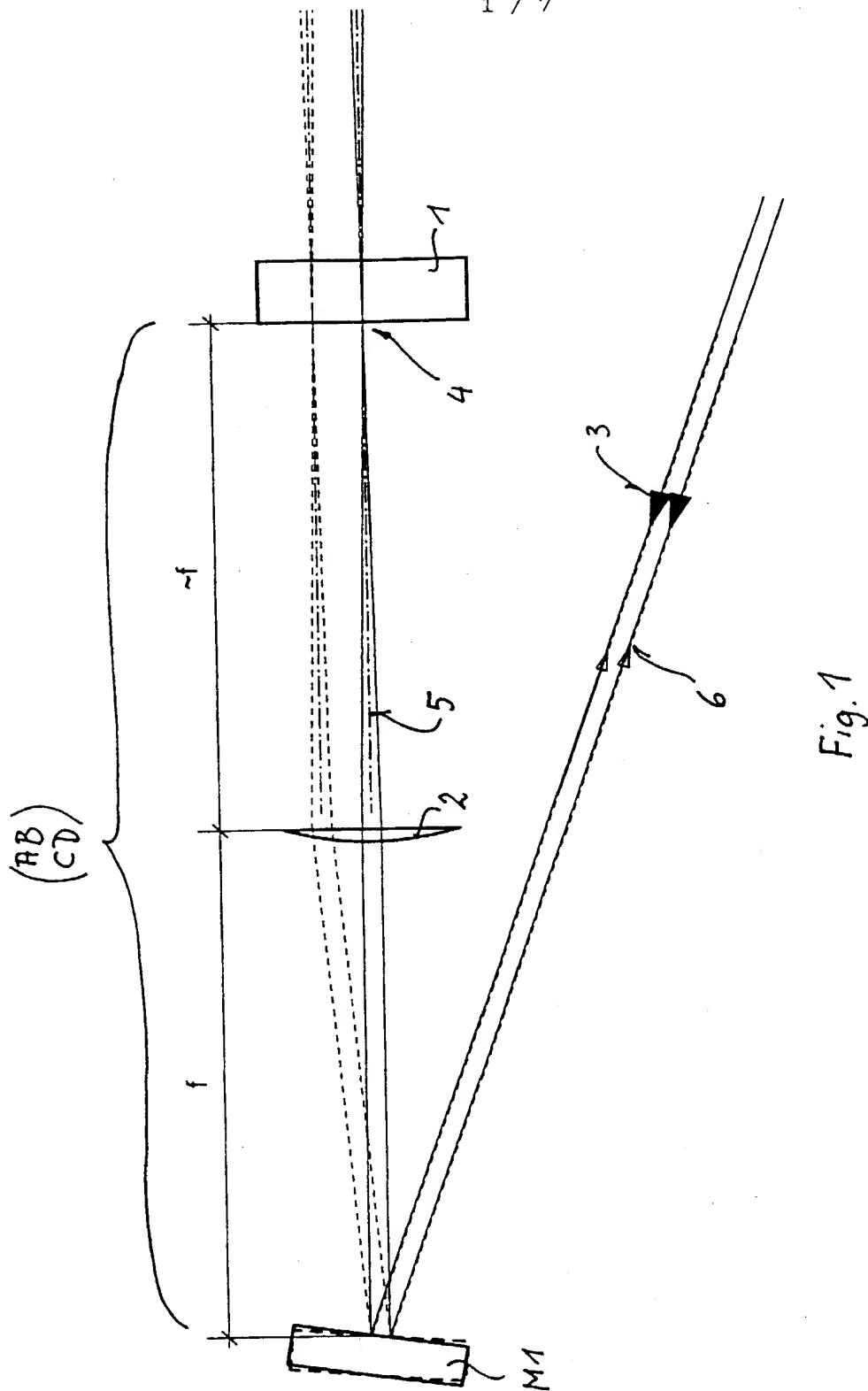
(54) Title: OPTICAL SYSTEM FOR LASERS



$$\begin{pmatrix} AB \\ CD \end{pmatrix} - \text{matrix, (I)}$$

(57) Abstract: An optical system for a laser comprises at least means for imaging a laser beam onto a first optical material (1, 1b). These imaging means comprise at least one optical imaging system (2) for focusing said laser beam onto the first optical material (1, 1b) and at least one optical means for changing the angle of the propagation axis of the laser beam, whereby the optical imaging system is positioned between the optical means and the first optical material, and may be described by formula (I) whereby D is substantially zero.

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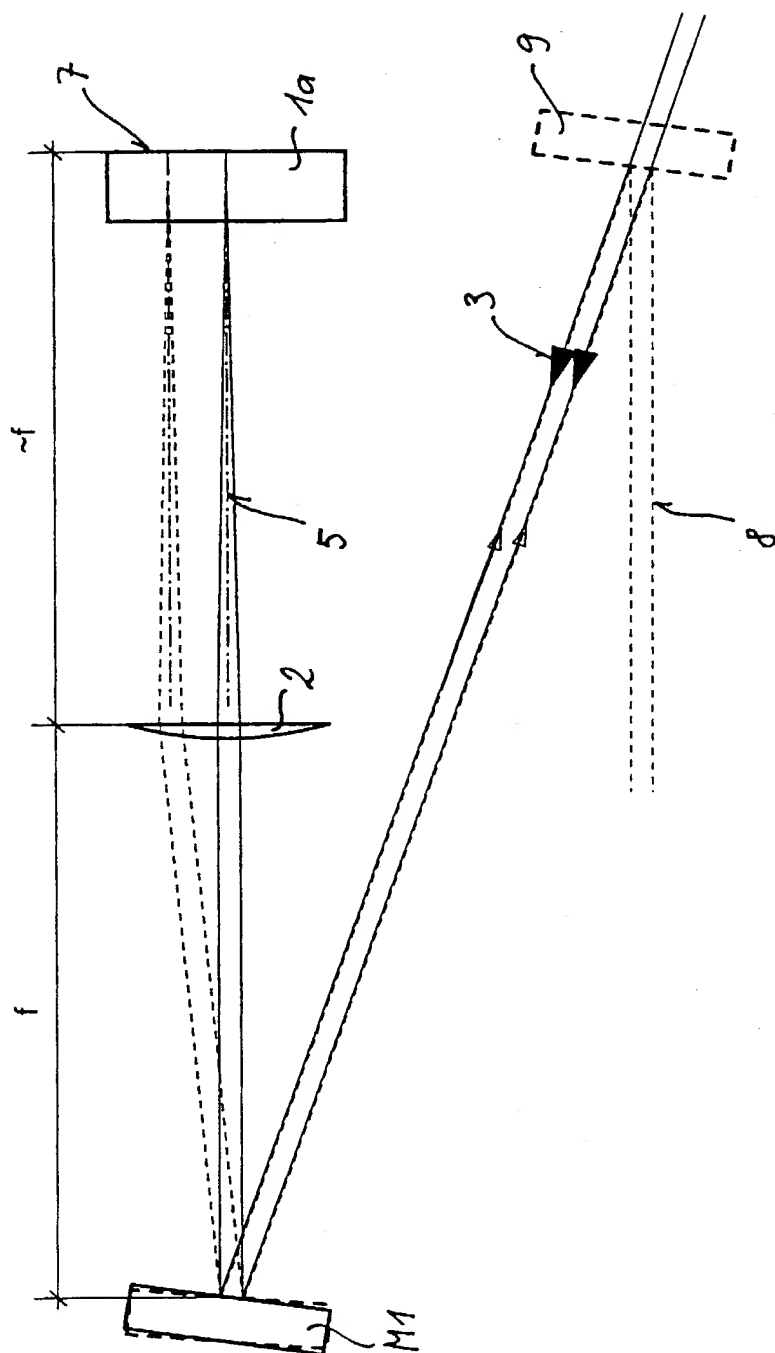
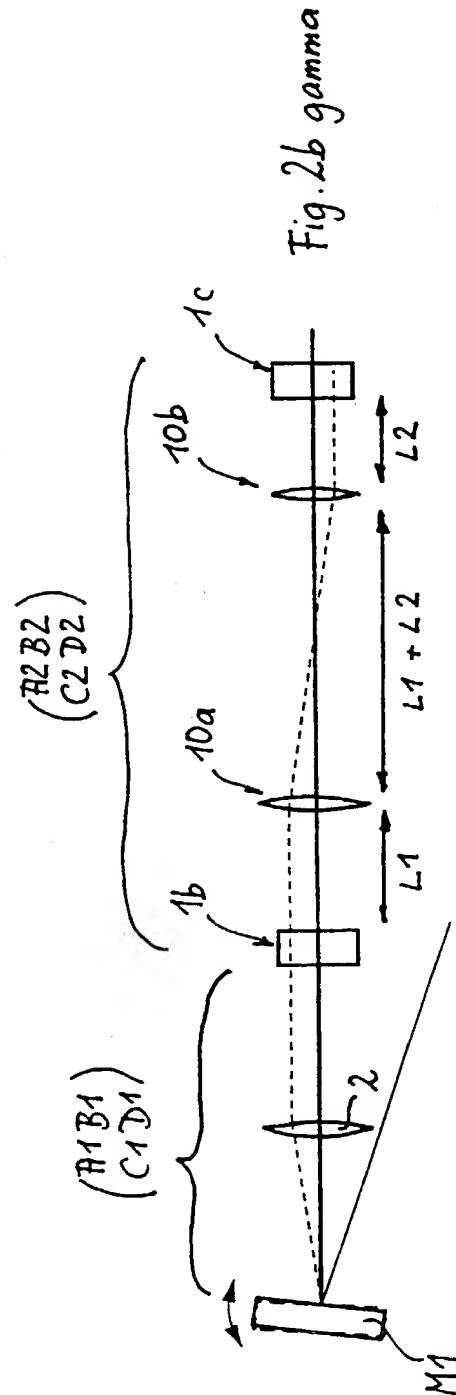
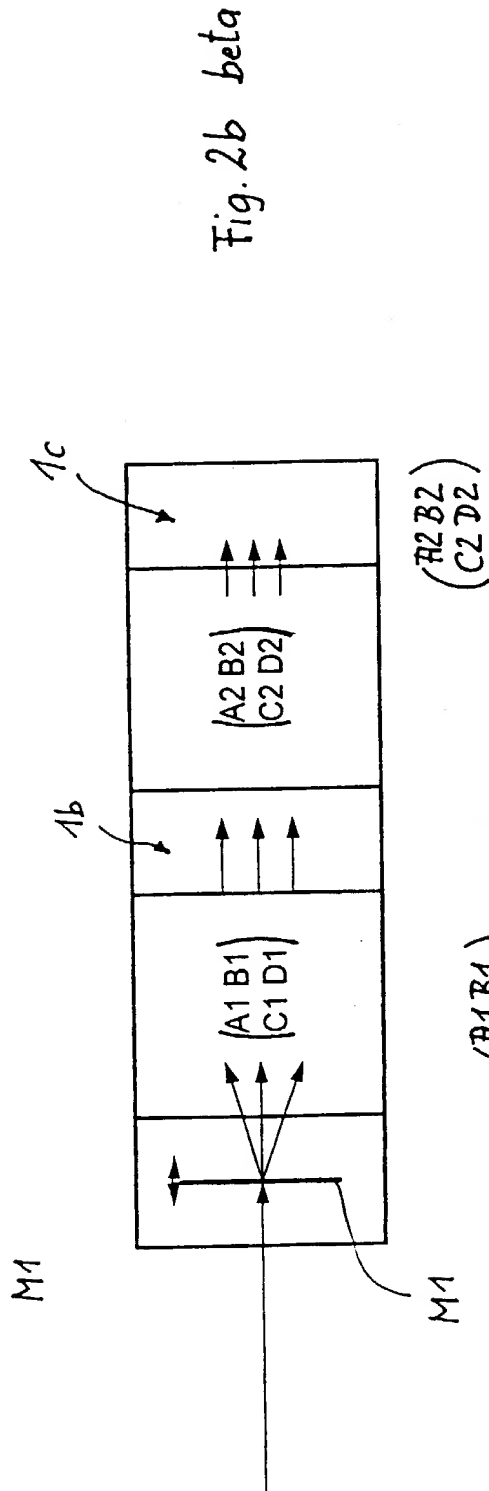
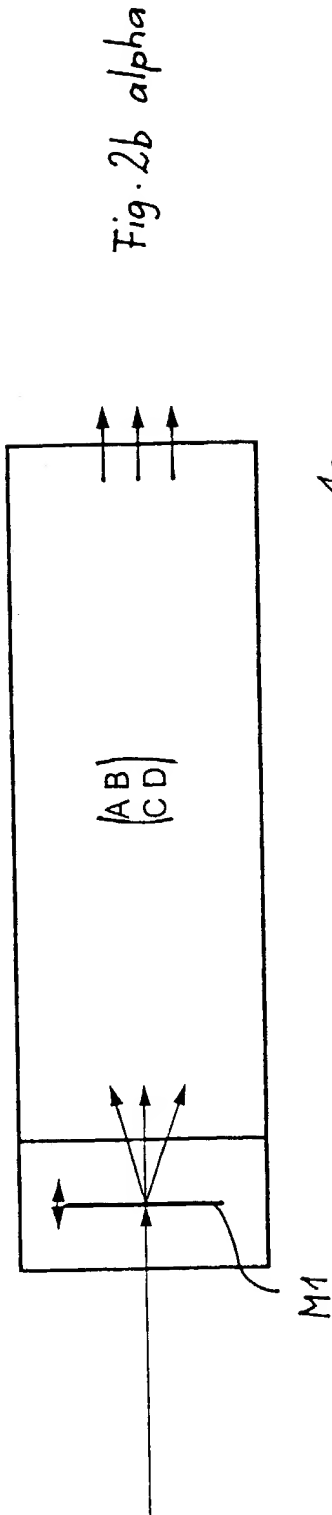


Fig. 2a



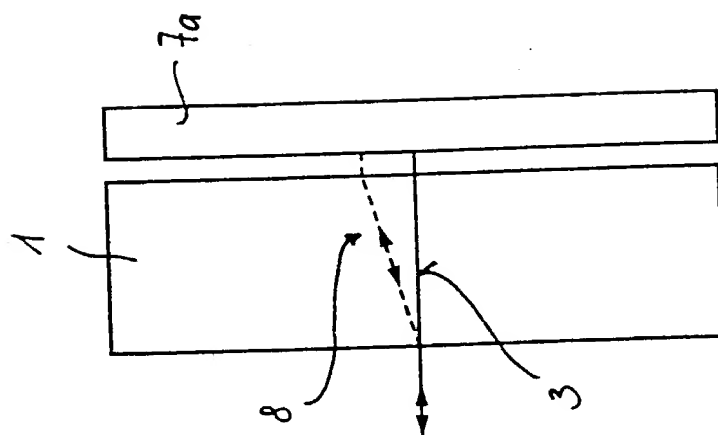


Fig. 3

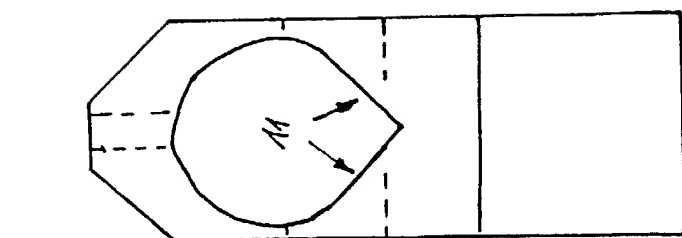


Fig. 4d

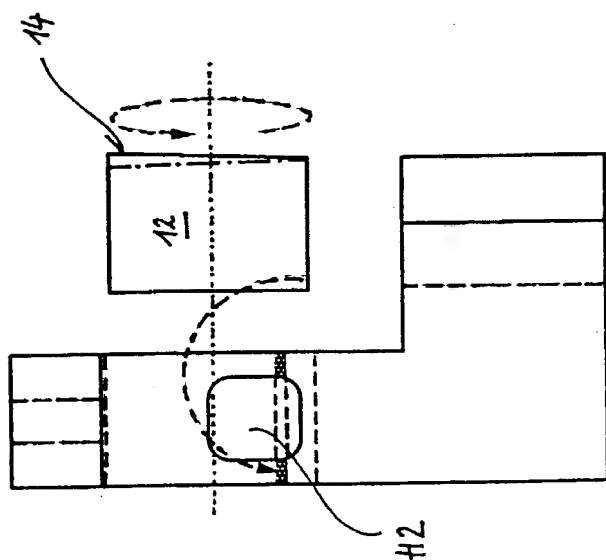


Fig. 4b

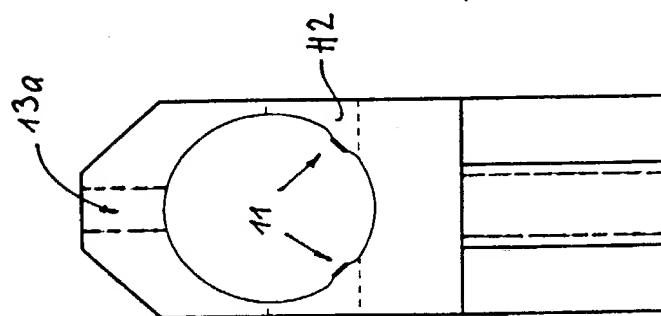


Fig. 4a

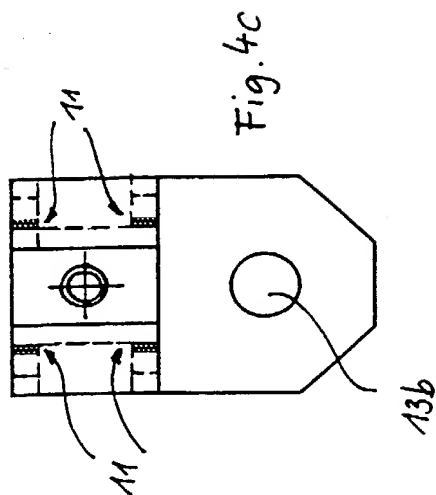


Fig. 4c

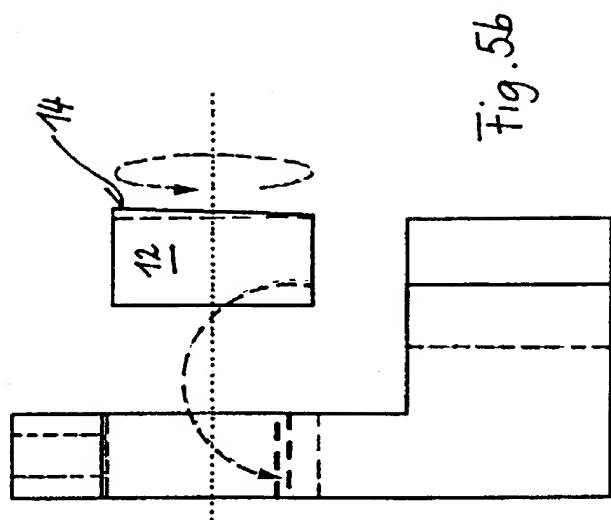


Fig. 5b

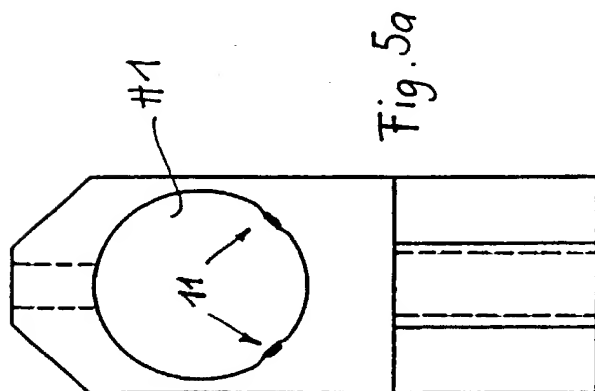


Fig. 5a

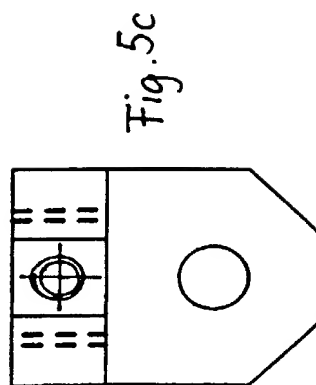


Fig. 5c

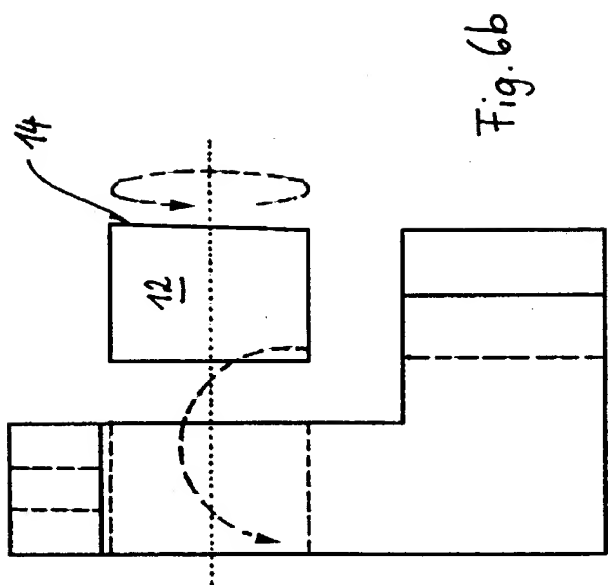


Fig. 6b

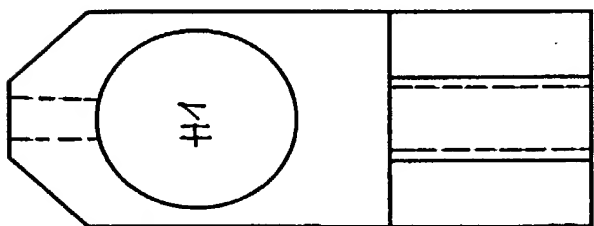


Fig. 6a

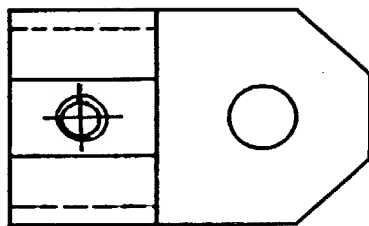


Fig. 6c



**DECLARATION AND POWER OF ATTORNEY  
UNDER 35 USC §371(c)(4) FOR  
PCT APPLICATION FOR UNITED STATES PATENT**

As a below named inventor, I hereby declare that:  
my residence, post office address and citizenship are as stated below under my name;

I verily believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought, namely the invention entitled: OPTICAL SYSTEM FOR LASERS  
described and claimed in international application number PCT/EP00/05203 filed June 7, 2000.

I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations §1.56.

Under Title 35, U.S. Code §119, the priority benefits of the following foreign application(s) filed by me or my legal representatives or assigns within one year prior to my international application are hereby claimed:

United States Patent Application No. 60/138,895 filed June 11, 1999.

The following application(s) for patent or inventor's certificate on this invention were filed in countries foreign to the United States of America either (a) more than one year prior to my international application, or (b) before the filing date of the above-named foreign priority application(s):

I hereby appoint the following as my attorneys of record with full power of substitution and revocation to prosecute this application and to transact all business in the Patent Office:

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Joel S. Armstrong, Reg. No. 36,430; Christopher W. Brown, Reg. No. 38,025; and  
Richard E. Rice, Reg. No. 31,560.

ALL CORRESPONDENCE IN CONNECTION WITH THIS APPLICATION SHOULD BE SENT TO OLIFF & BERRIDGE, PLC, P.O. BOX 19928, ALEXANDRIA, VIRGINIA 22320, TELEPHONE (703) 836-6400.

I hereby declare that I have reviewed and understand the contents of this Declaration, and that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

1-00

1	Typewritten Full Name of Sole or First Inventor	Daniel		KOPF
		Given Name	Middle Initial	Family Name
2	Inventor's Signature:	<i>[Signature]</i>		
3	Date of Signature:	18 Feb. 2002		
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	Citizenship:	Austria		
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	(Insert complete mailing address, including country)	Austria		

Note to Inventor: Please sign name on line 2 exactly as it appears in line 1 and insert the actual date of signing on line 3.

IF THERE IS MORE THAN ONE INVENTOR USE PAGE 2 AND PLACE AN "X" HERE ☐  
(Discard this page in a sole inventor application)